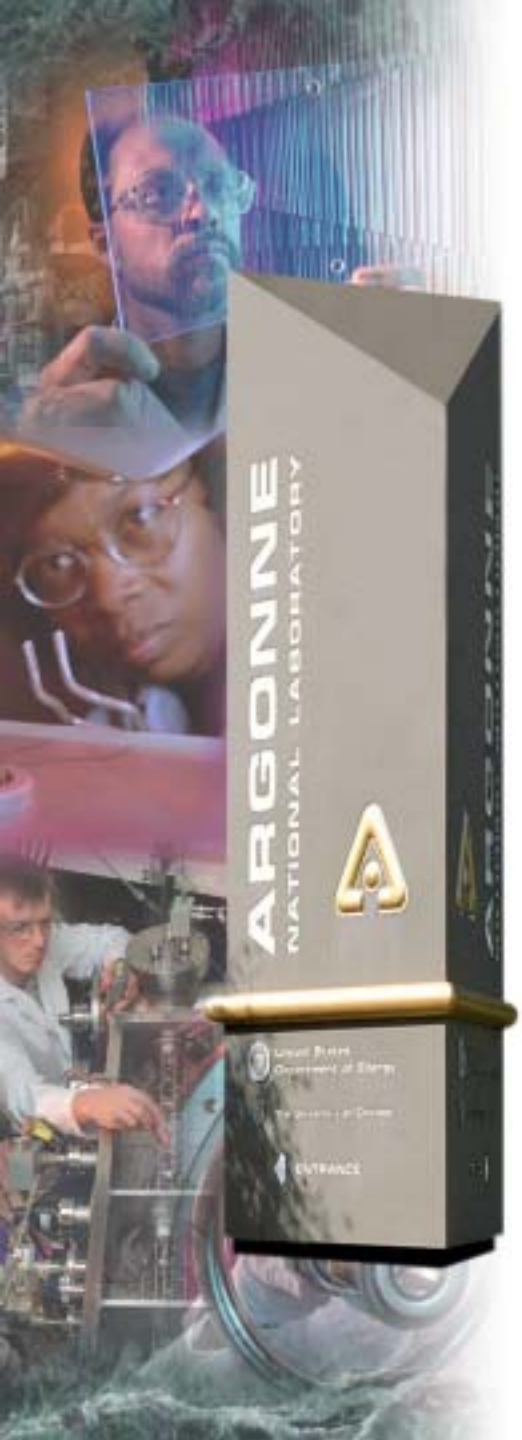


Introduction to the APS

George Srajer

Nanomagnetism Workshop, Aug. 29 - Sep. 1, 2004
Fontana, Wisconsin

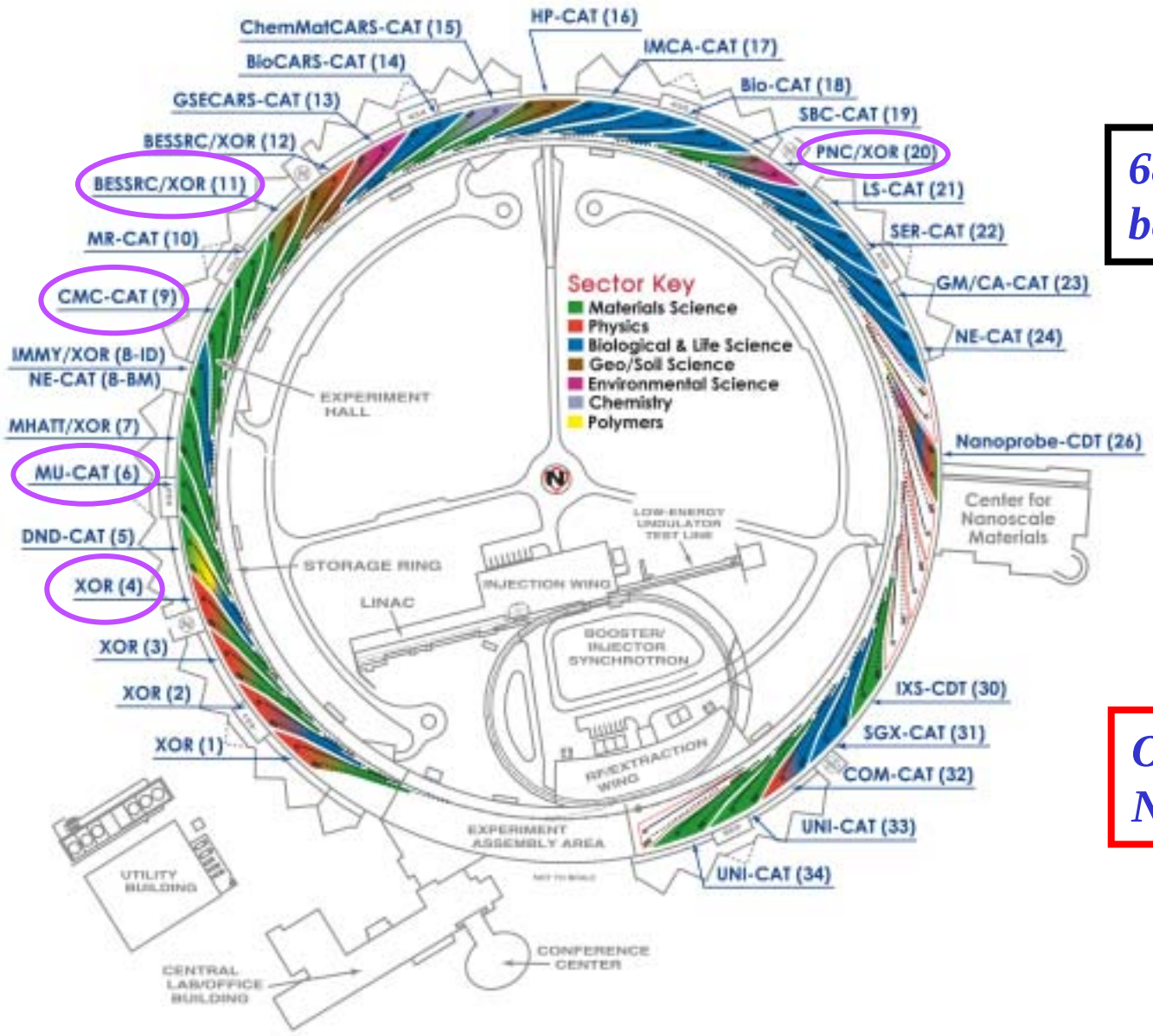
Argonne National Laboratory

A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago

Office of Science
U.S. Department of Energy

The Advanced Photon Source

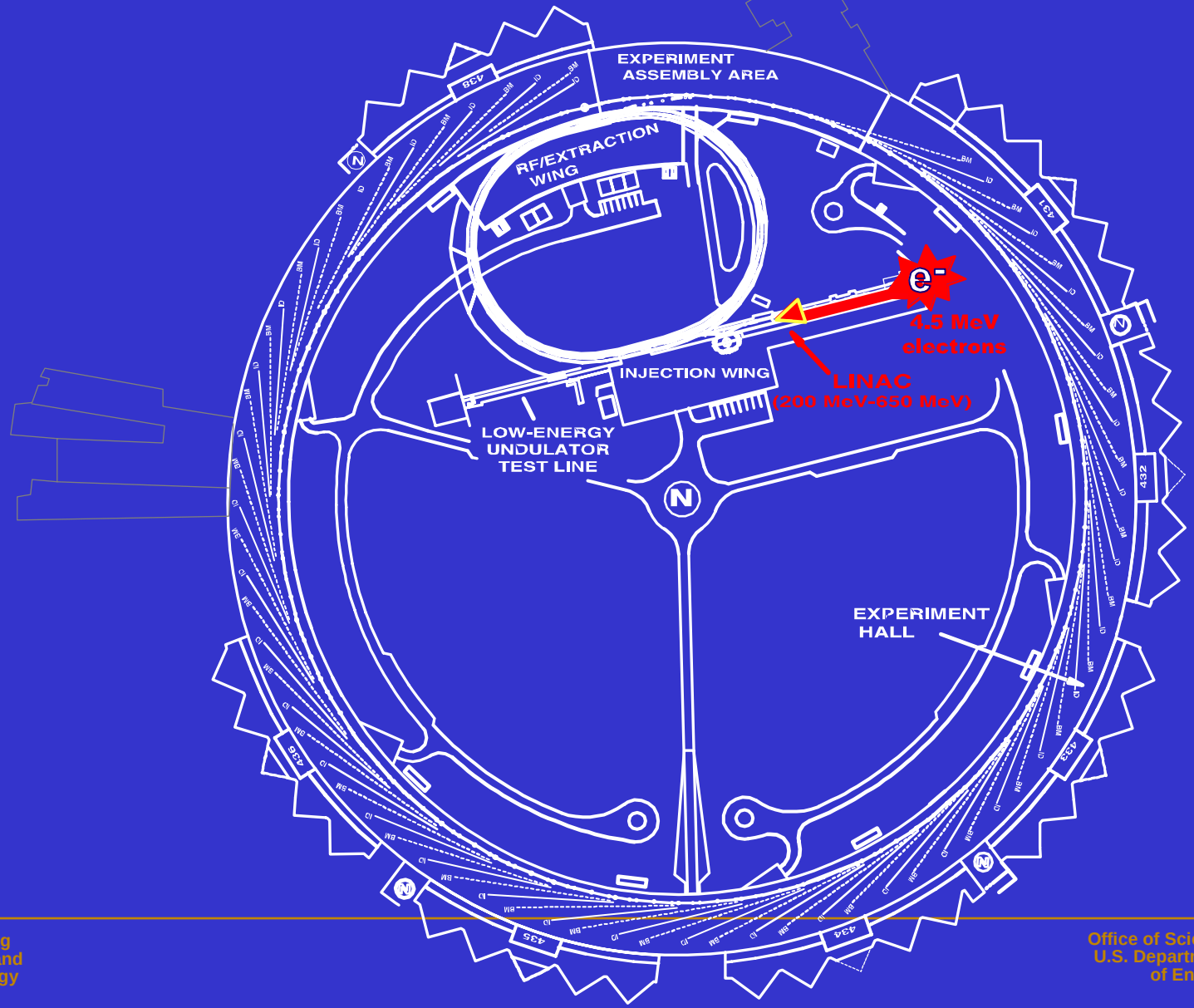
Experimental Hall Plan



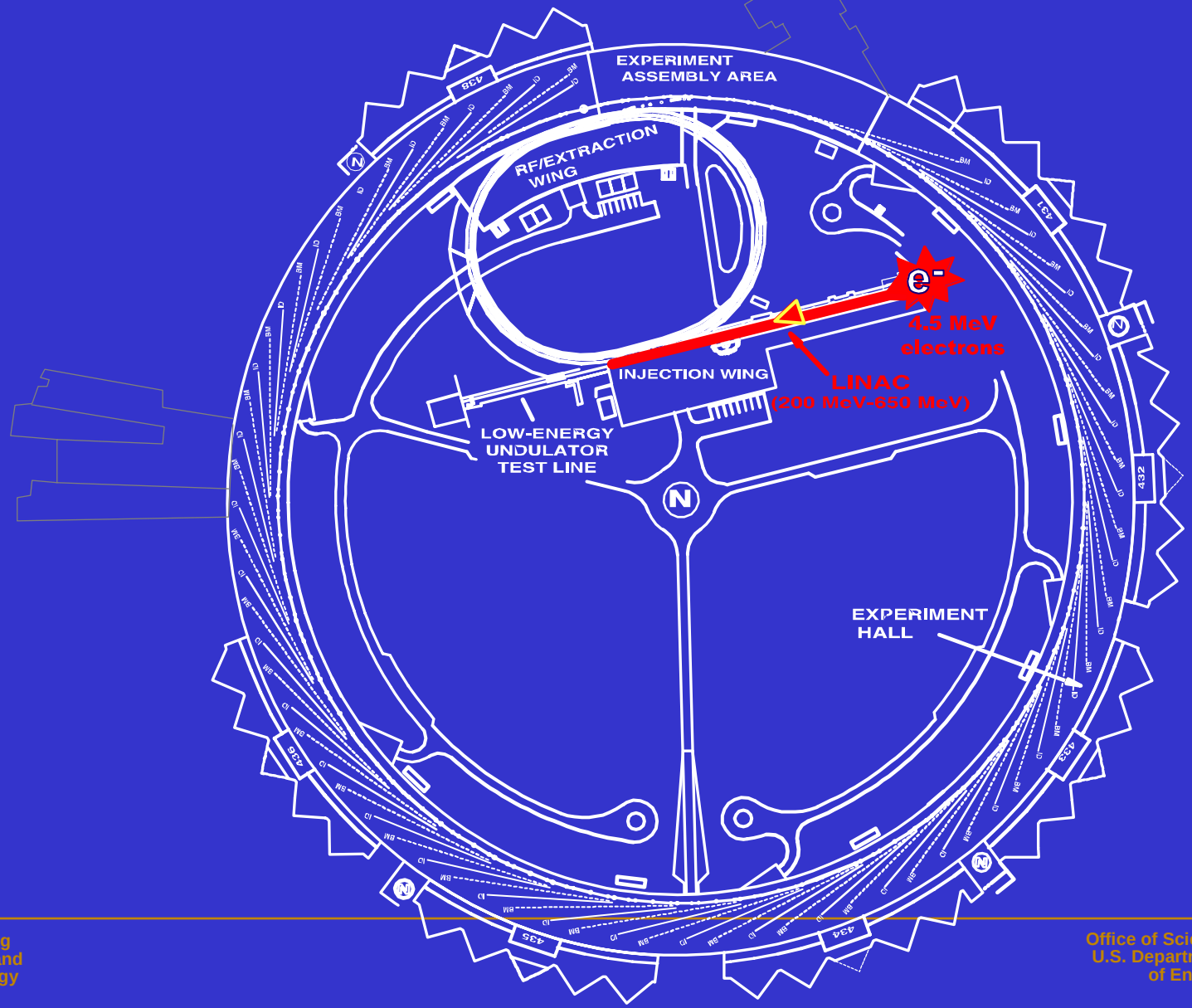
68 total available beamports

Only 4 ID ports Not yet committed

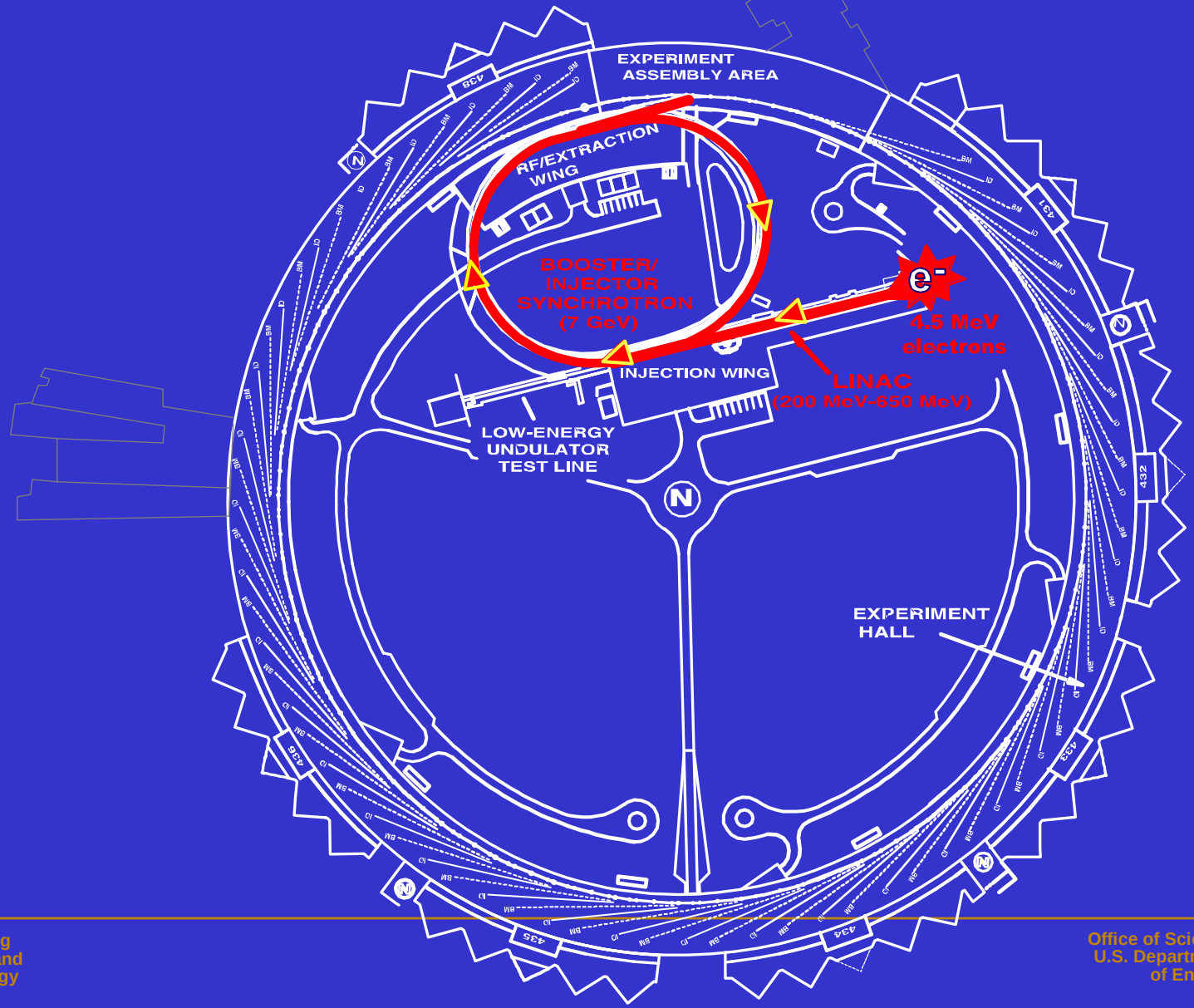
Linear accelerator raises electron energy to 325 MeV



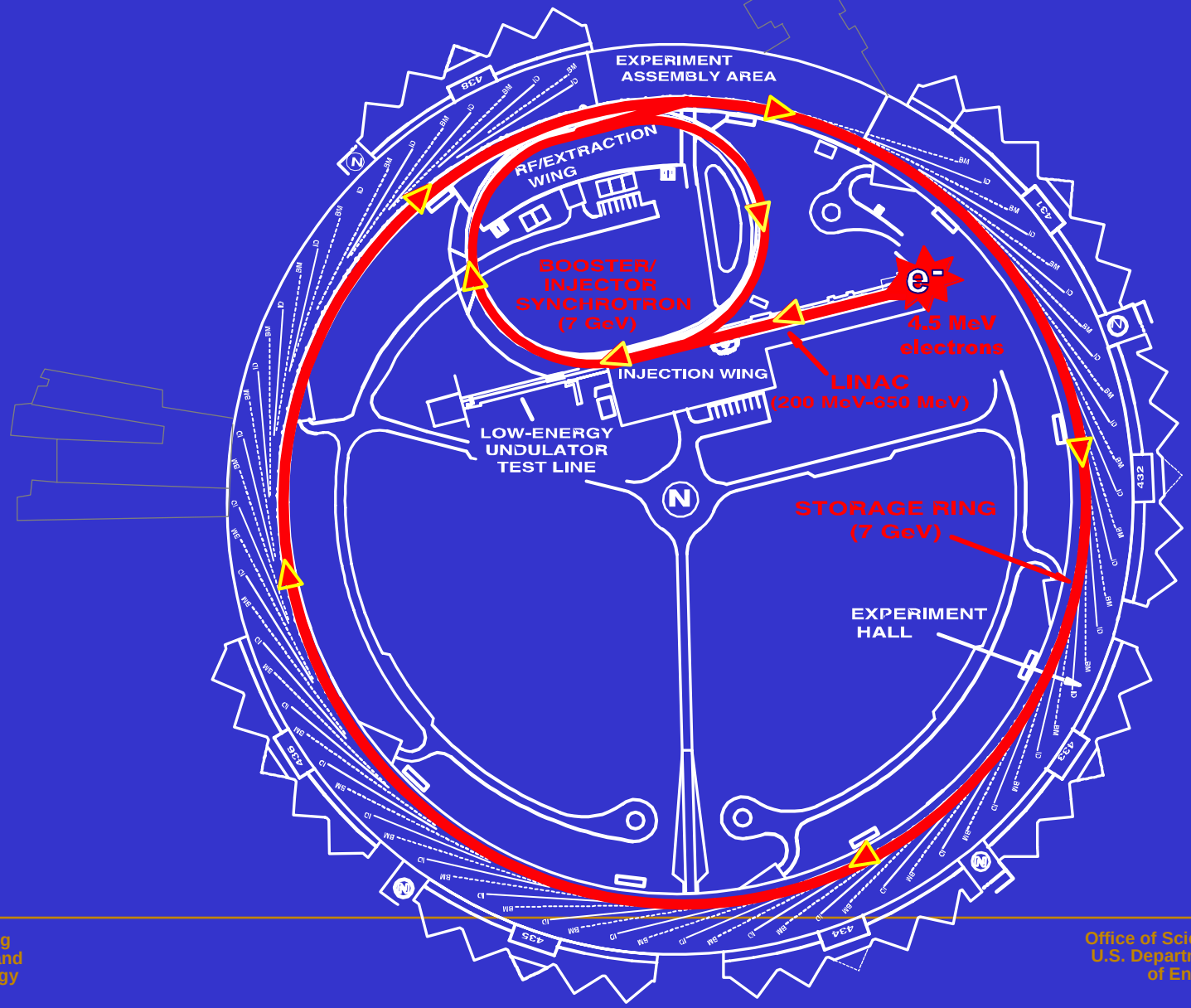
Electrons are injected into 368 m long booster synchrotron



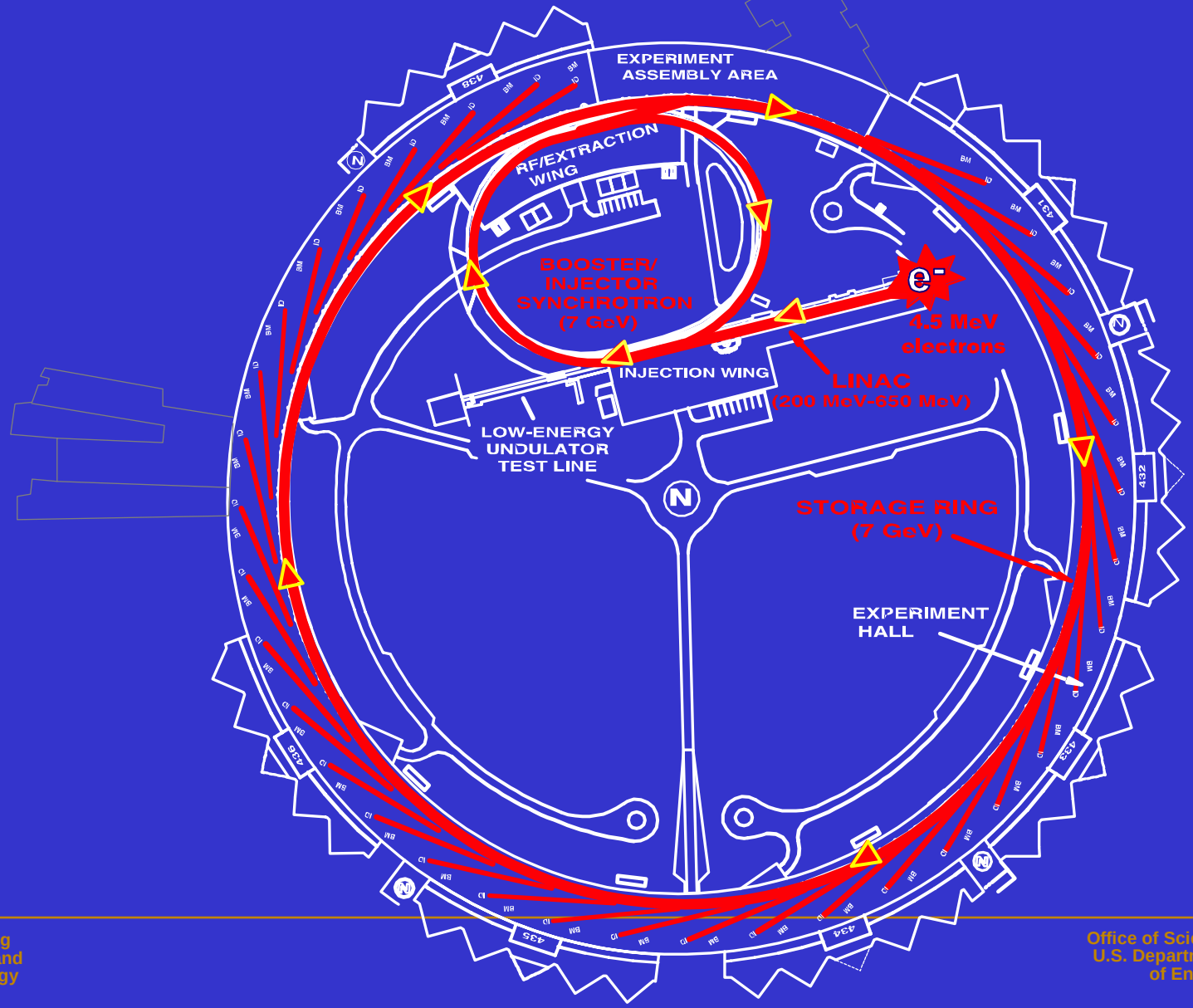
Booster raises electron energy to 7 GeV



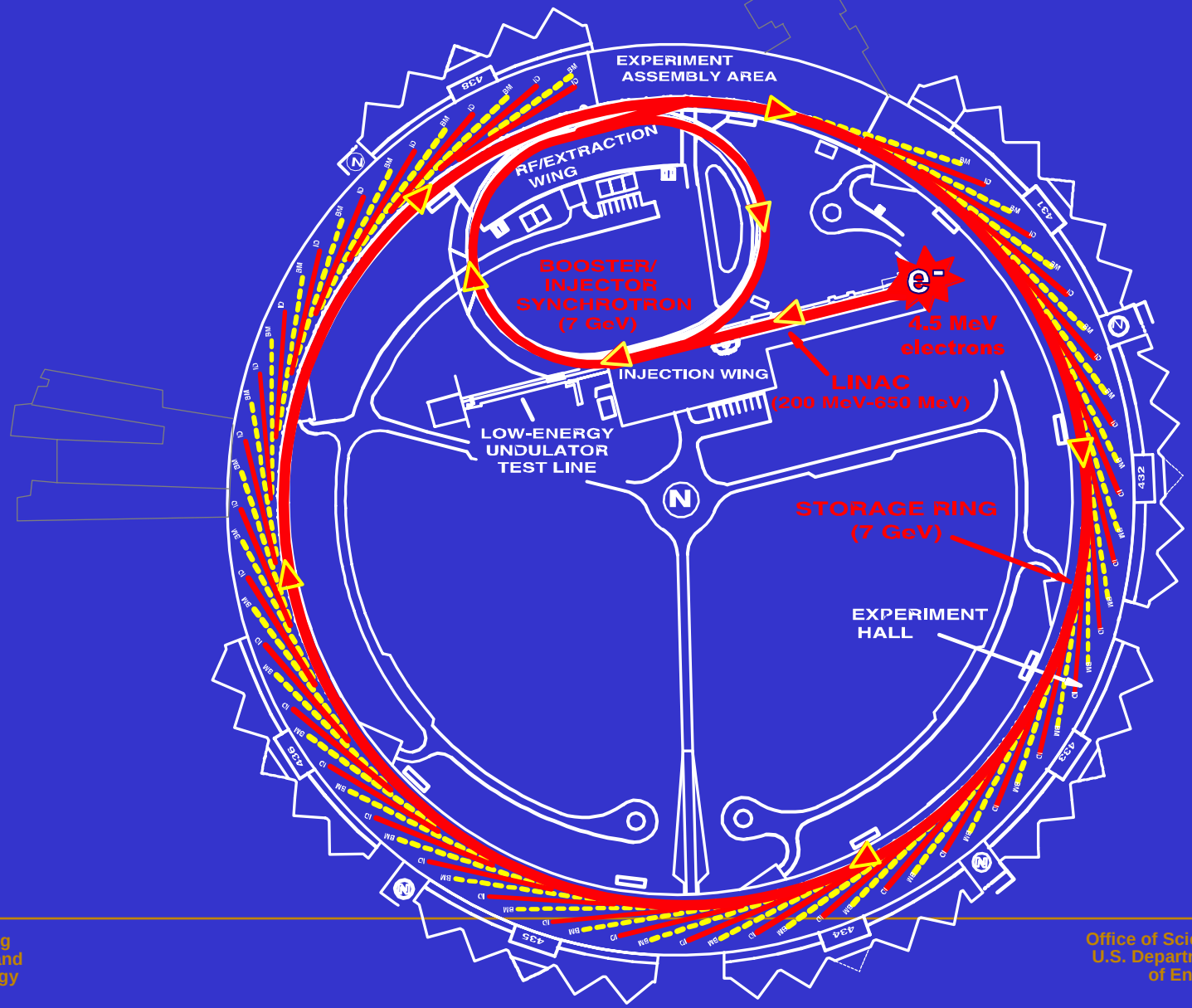
7 GeV electrons injected into 1104 m circumference storage ring



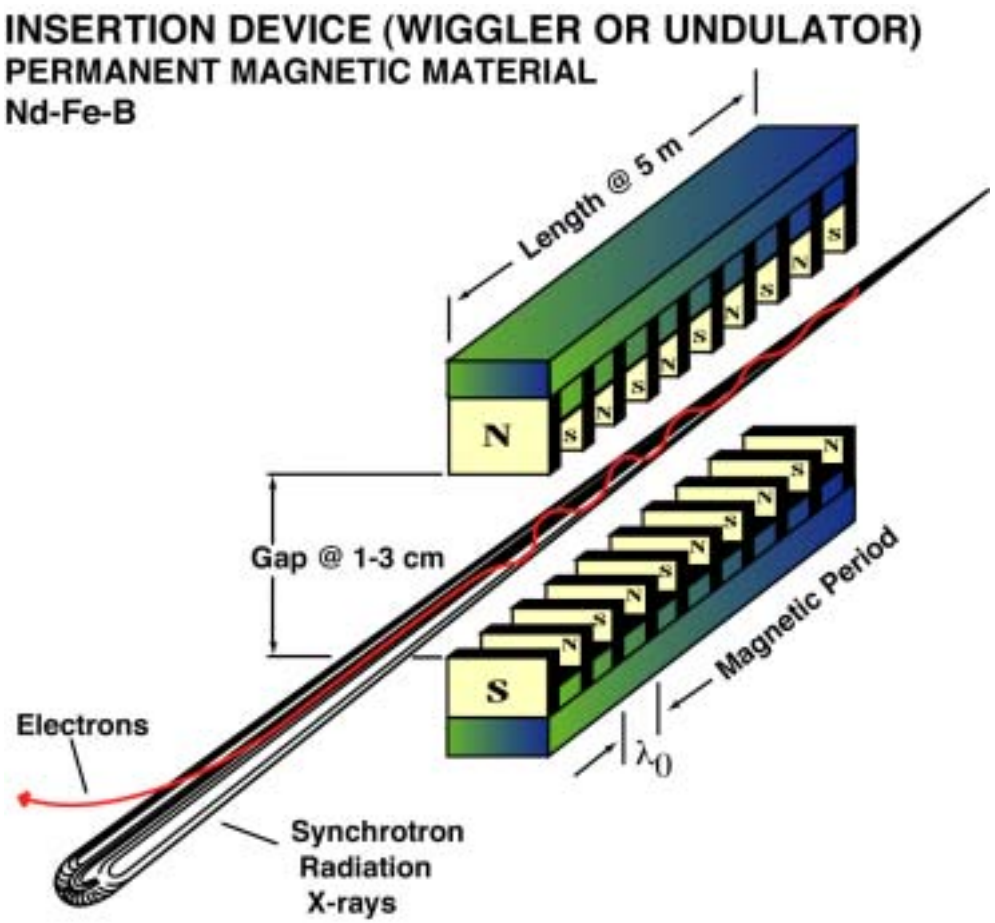
Electrons orbit in the storage ring emitting synchrotron radiation to insertion device beamlines

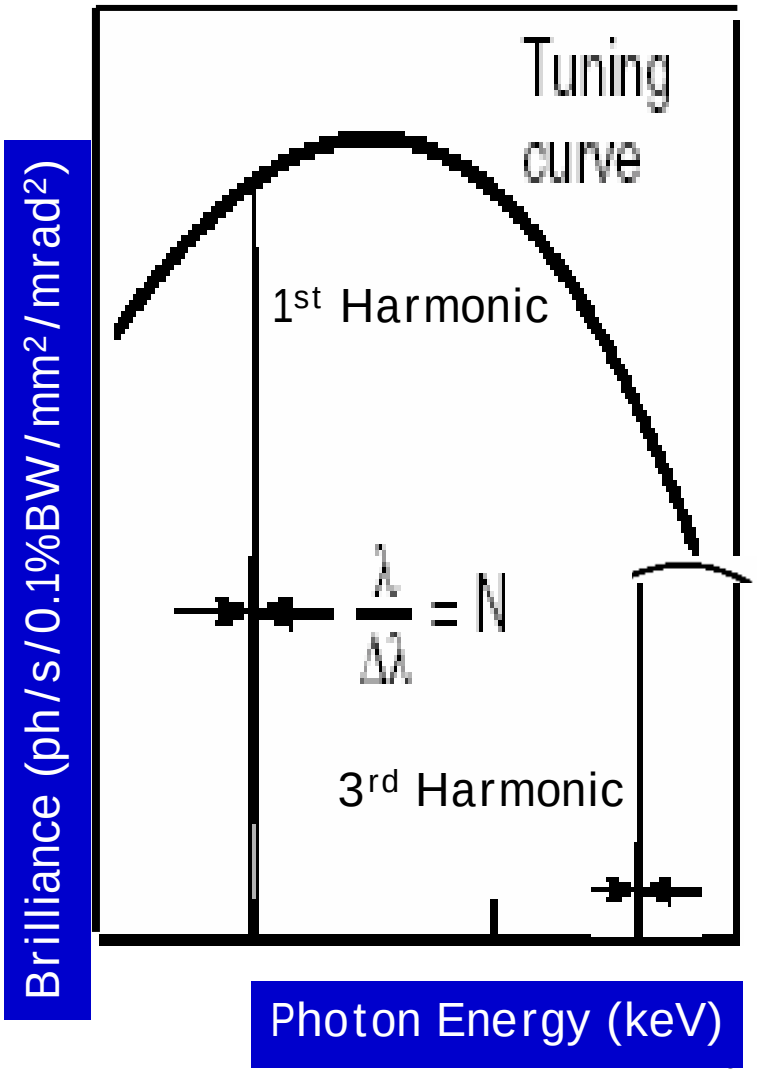


… and bending magnet beamlines

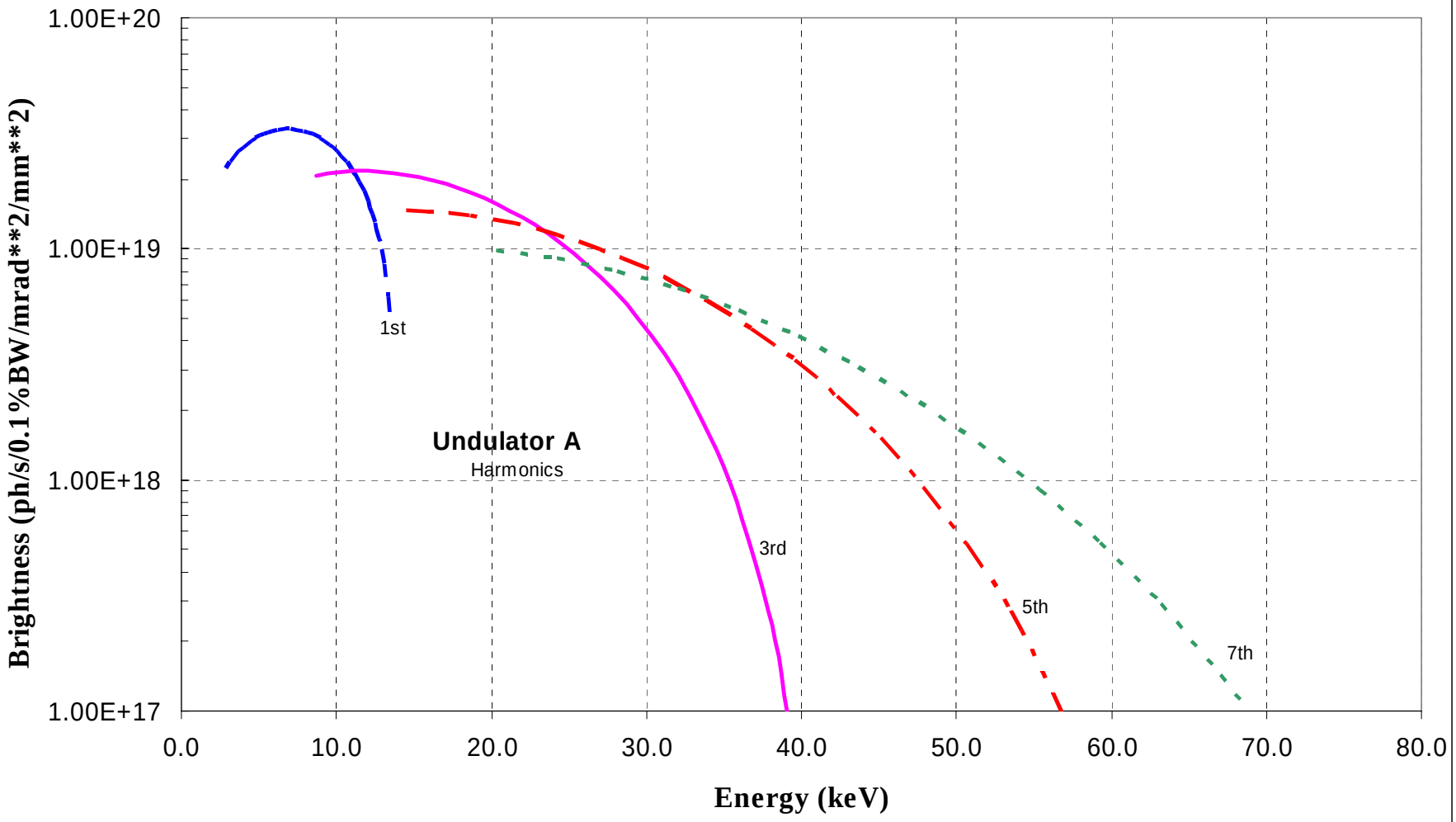


APS is a Third-Generation Synchrotron Source

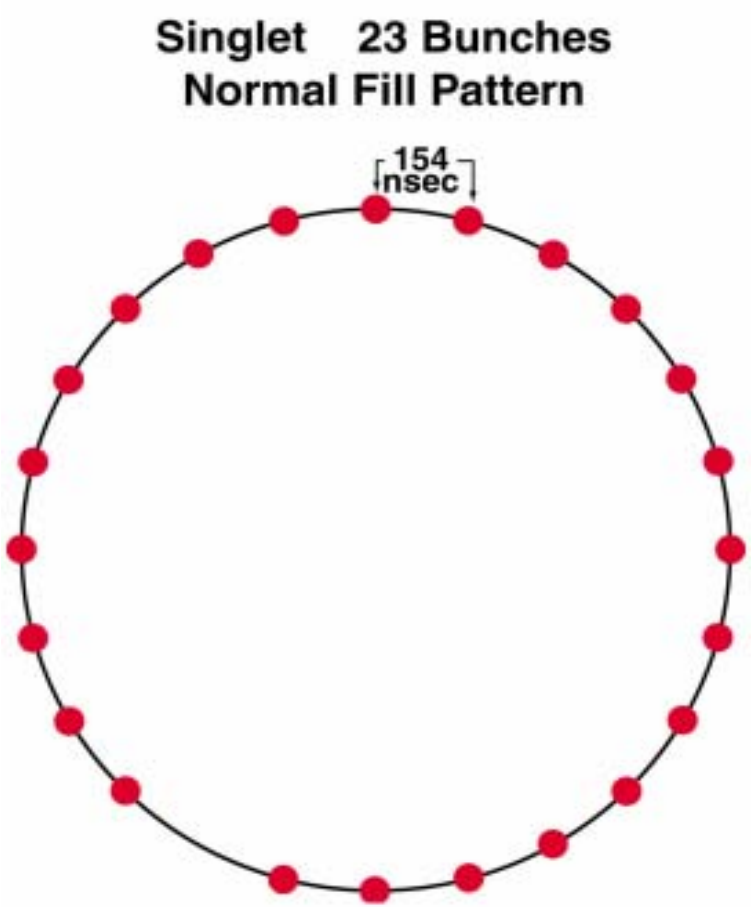


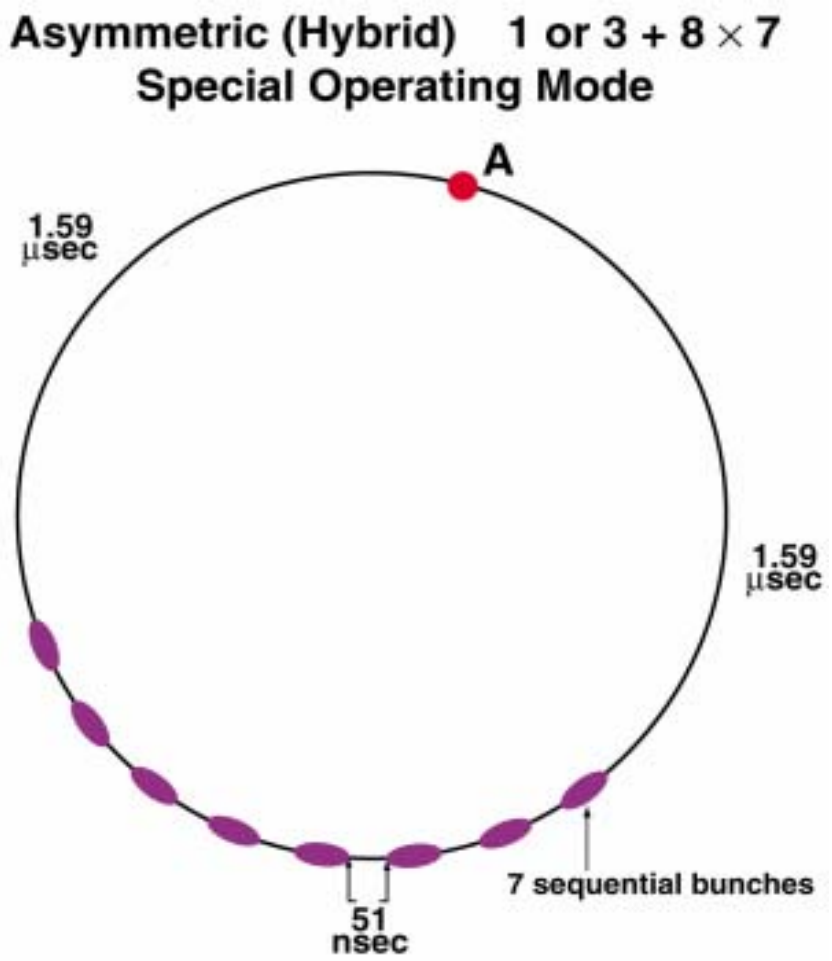


Tunability of Spectral Brilliance



APS is a Pulsed Source

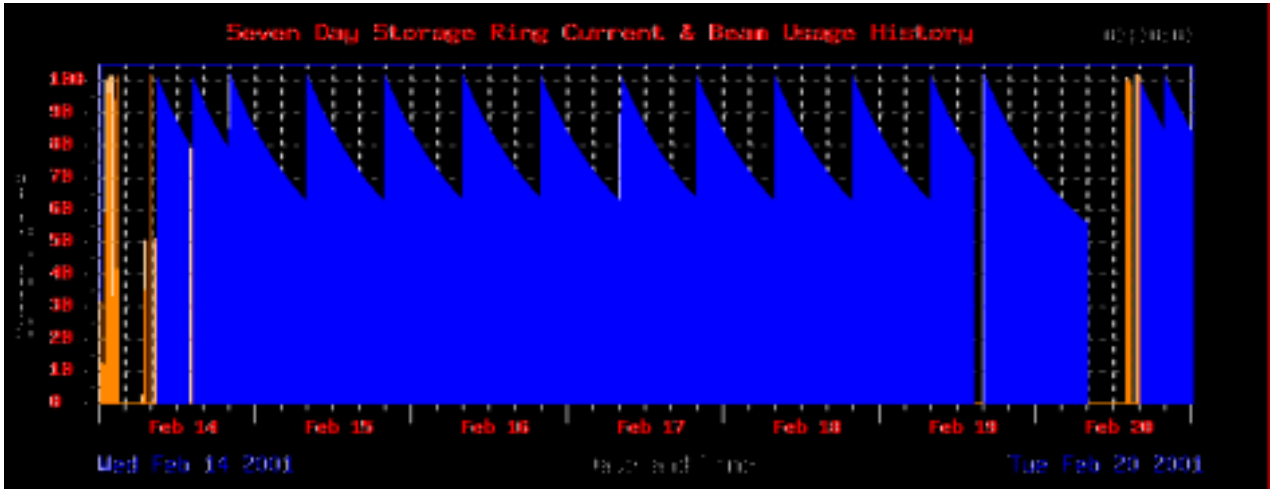




Timing experiments!

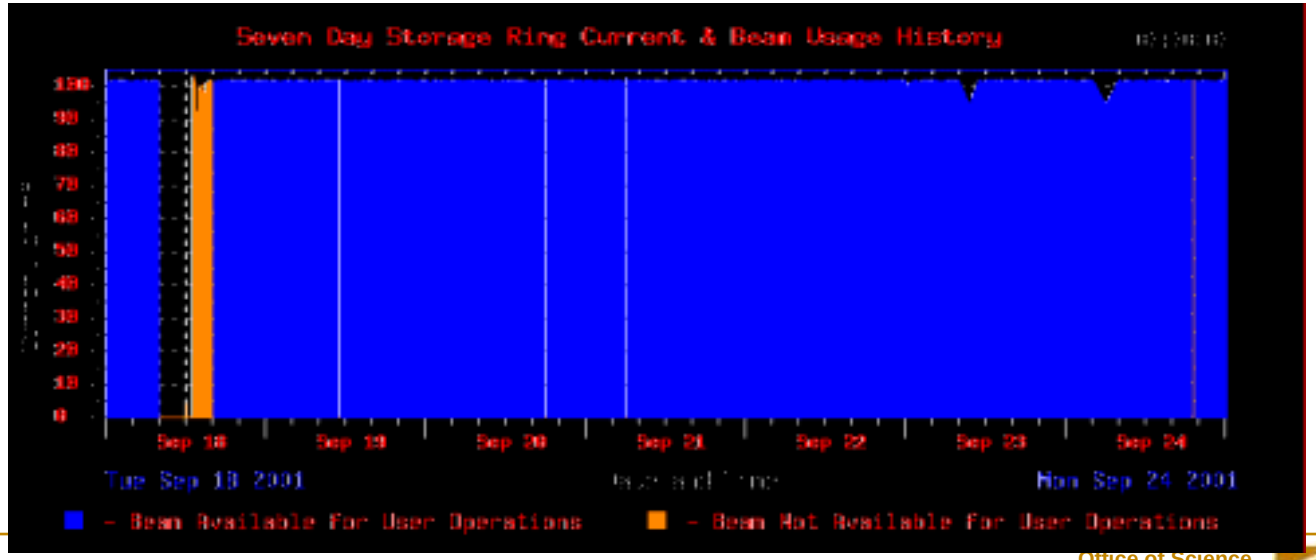
Constant Current Operation at the APS

Conventional fill



Constant current

or “top-up”



APS Parameters

Storage ring energy	7.0 GeV
Storage ring current	100 mA
Horizontal emittance, ε_x	3.0 nm-rad
Vertical emittance, ε_y	0.03 nm-rad
Beam energy spread, dE/E	0.096 (%)
Coupling constant	1%
Horizontal beta function, β_x	14.4 m
Vertical beta function, β_y	4.0 m
Dispersion function, h_x	0.124 m
Orbital period	~ 3.6 ms

$\Rightarrow$ ***High brilliance***

Bottom line: Lots of photons in a small area !!

Synchrotron Sources

What are they good for:

1. Energy tunability → Element specificity

Enables studies of heterogeneous systems

2. High brilliance → High flux density

Enables studies of small and dilute samples

3. High momentum resolution → High spatial resolution

Enables studies of surfaces and interfaces

4. Timing structure

Enables studies of time-dependent processes

Synchrotrons for Magnetism

Separate orbital and spin contributions

"Obstacles" for Using Synchrotron Sources

- **Lack of familiarity with techniques**
- **Often complicated interaction mechanism**
- **Synchrotron sources are not in your backyard**

Application of synchrotron-based techniques for magnetism studies became a viable tool only in the last ~ 10 years

Interaction of X-rays with Matter

Scattering of x-rays from electrons in a periodic medium

(Blume and Gibbs, PRB **37**, 1779 (1988)):

$$\frac{d\sigma}{d\Omega} = r_o^2 \left| \sum_n e^{i\vec{Q}\cdot\vec{r}_n} f_n\left(\vec{k},\vec{k}',\hbar\omega\right) \right|^2$$

Scattering amplitude:

$$f\left(\vec{k},\vec{k}',\omega\right) = f^{charge}\left(\vec{Q}\right) + f'\left(\vec{k},\vec{k}',\omega\right) + if''\left(\vec{k},\vec{k}',\omega\right) + f^{spin}\left(\vec{k},\vec{k}',\omega\right)$$

$f^{charge} \rightarrow$ Thomson scattering

f' and f'' $\rightarrow$ energy-dependent contributions

$f^{spin} \rightarrow$ scattering from spins of electrons

At 10 keV:

$$\frac{f^{spin}}{f^{charge}} = 0.02$$

Scattering Cross Sections

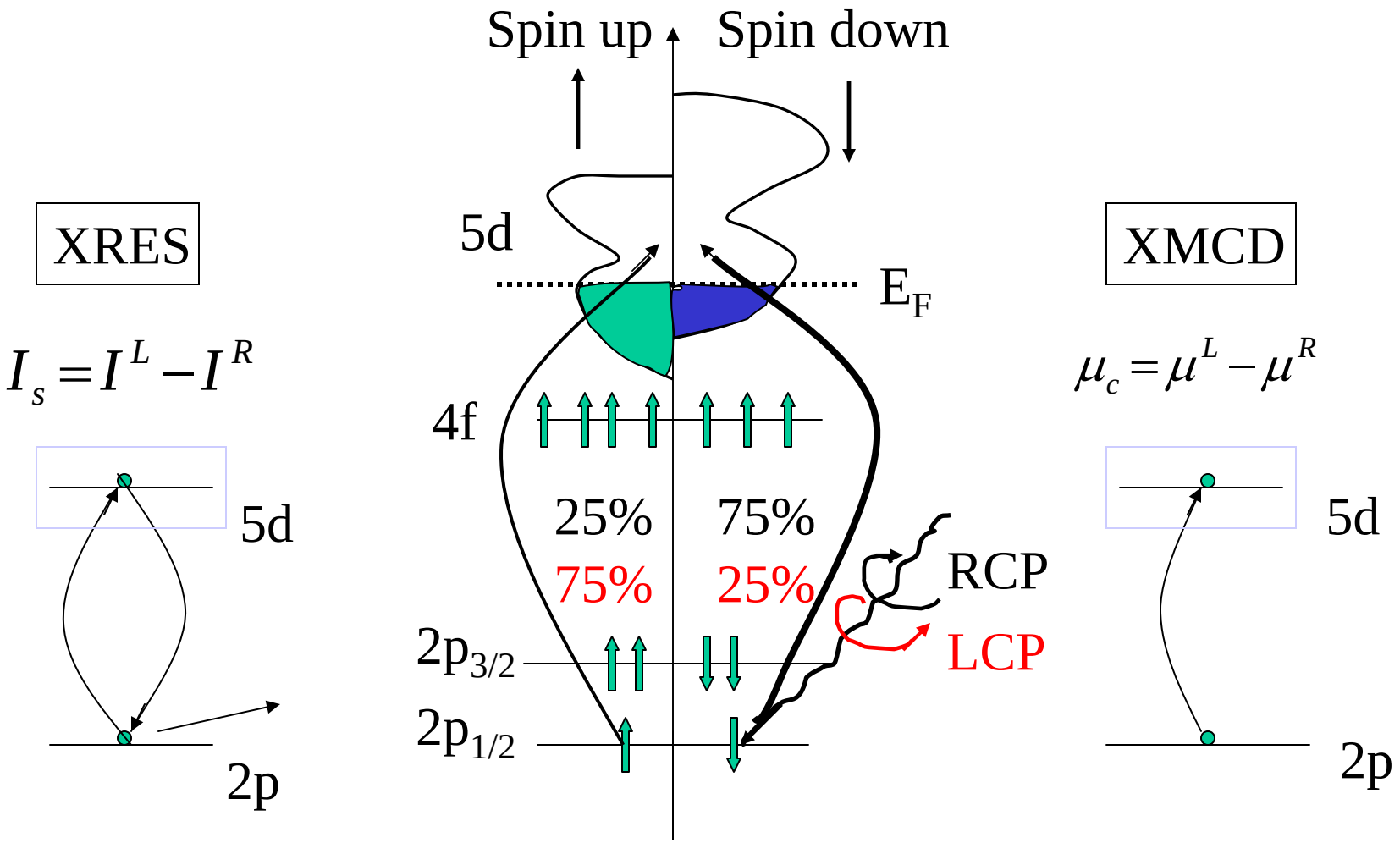
Nonresonant:

$$f = f^{charge} + f^{magnetic} = \rho(Q)\ \hat{\varepsilon}' \cdot \hat{\varepsilon} + ir_o \left(\frac{\hbar\omega}{m_e c^2} \right) \left[\frac{1}{2} \vec{L}(Q) \cdot \vec{A} + \vec{S}(Q) \cdot \vec{B} \right]$$

Resonant (dipole only):

$$f^{res} = F^0 \left(\hat{\varepsilon}_f \cdot \hat{\varepsilon}_i \right) - iF^1 \left(\hat{\varepsilon}_f \times \hat{\varepsilon}_i \right) \bullet \hat{m}_n + F^2 \left(\hat{\varepsilon}_f \cdot \hat{m}_n \right) \left(\hat{\varepsilon}_i \cdot \hat{m}_n \right)$$

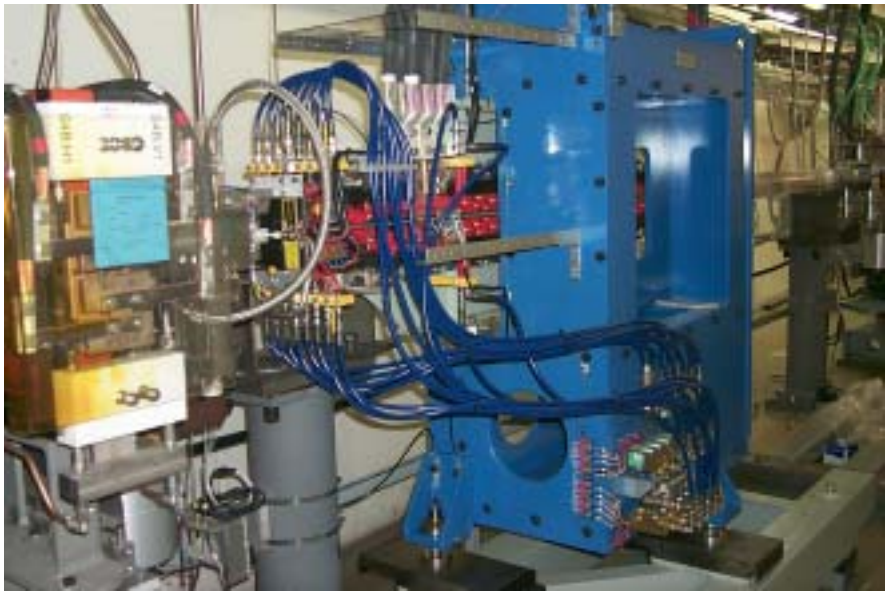
Magnetic Sensitivity with Circularly Polarized Beam

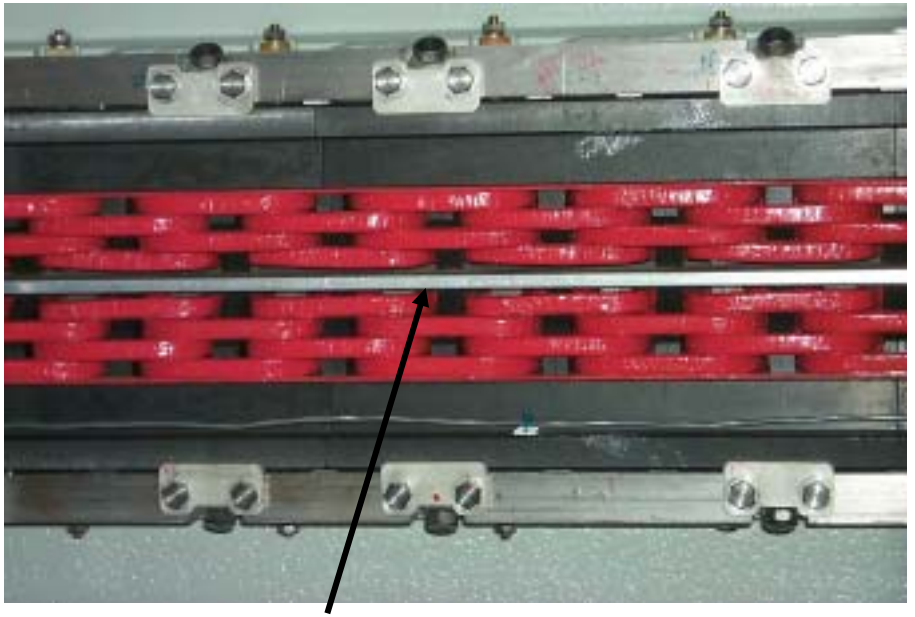


Specialized Circularly Polarized Undulator

Fully electromagnetic insertion device in XOR-4

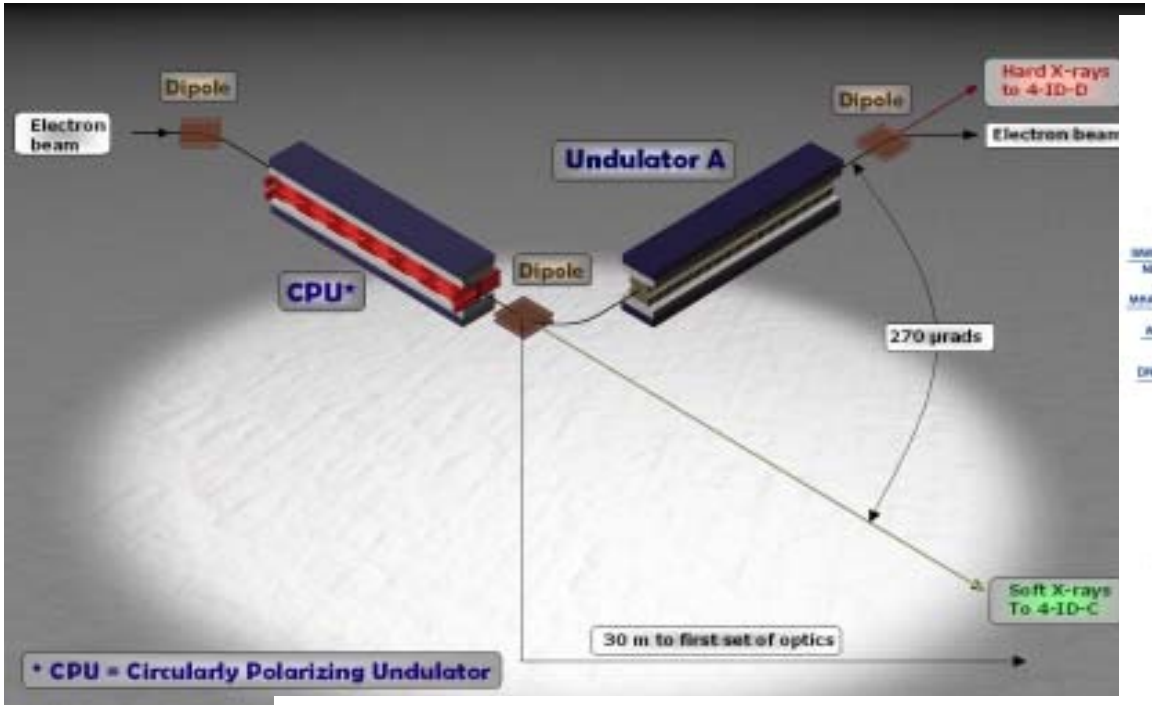
Produces left and right circular (P_c > 96%) and horizontal and vertical linear polarization



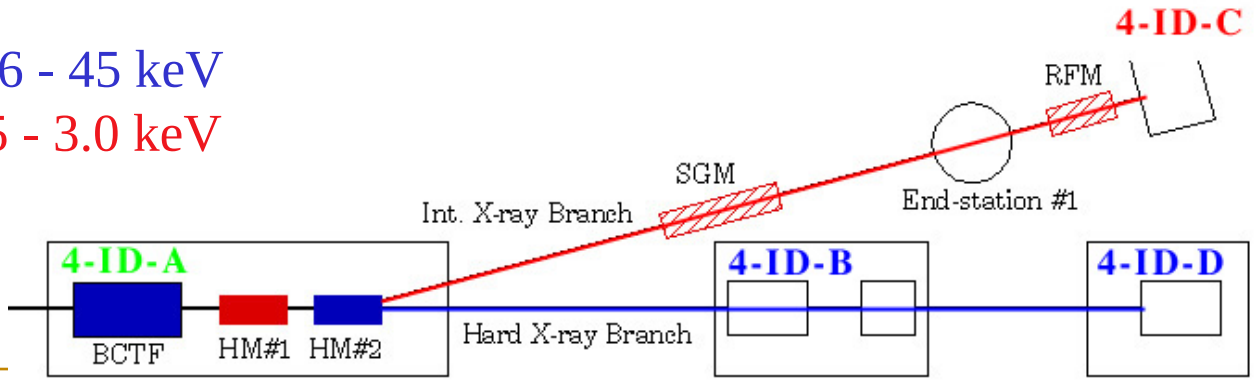


Storage ring vacuum chamber

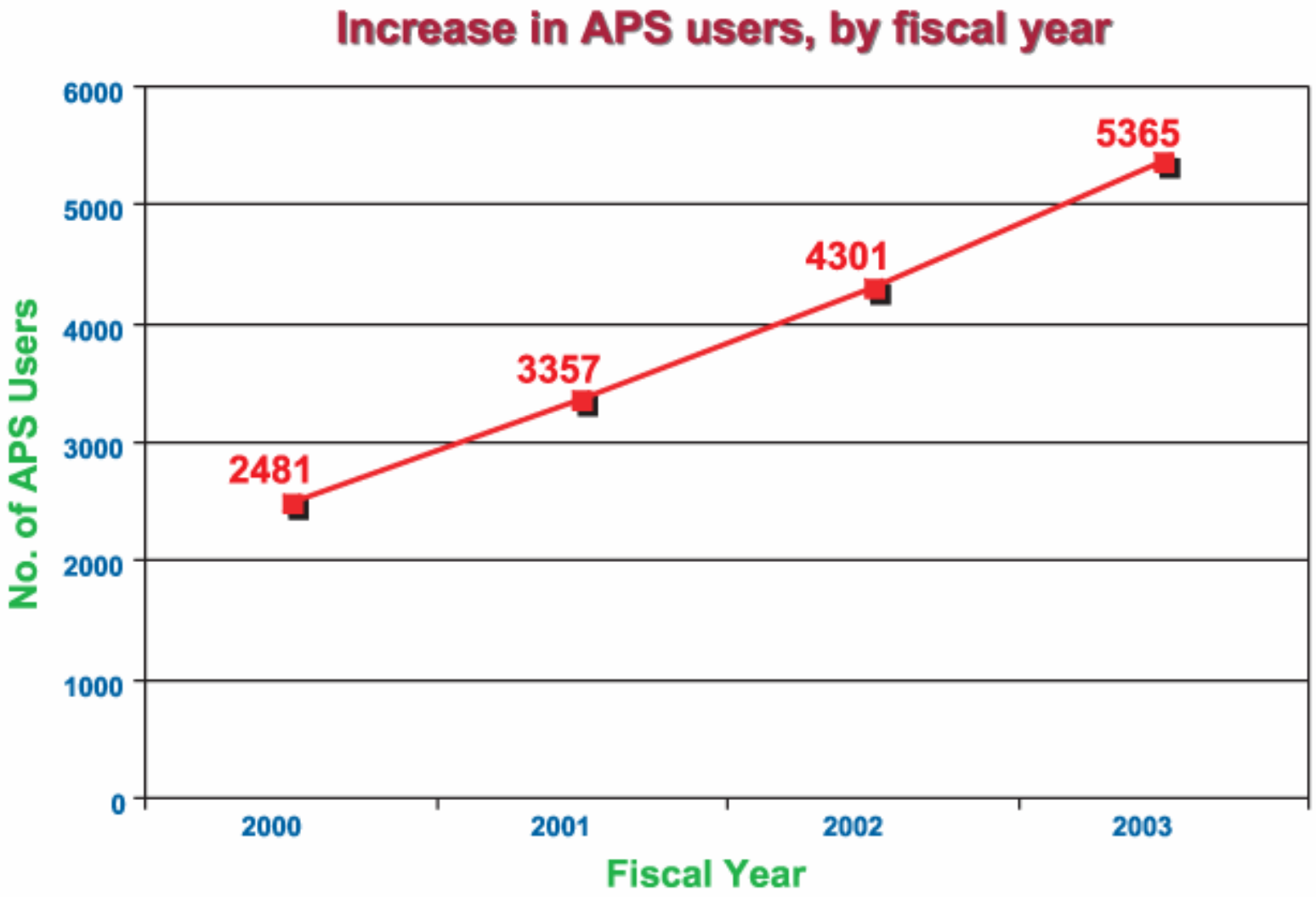
Dedicated Beamlines for Magnetism Studies at APS



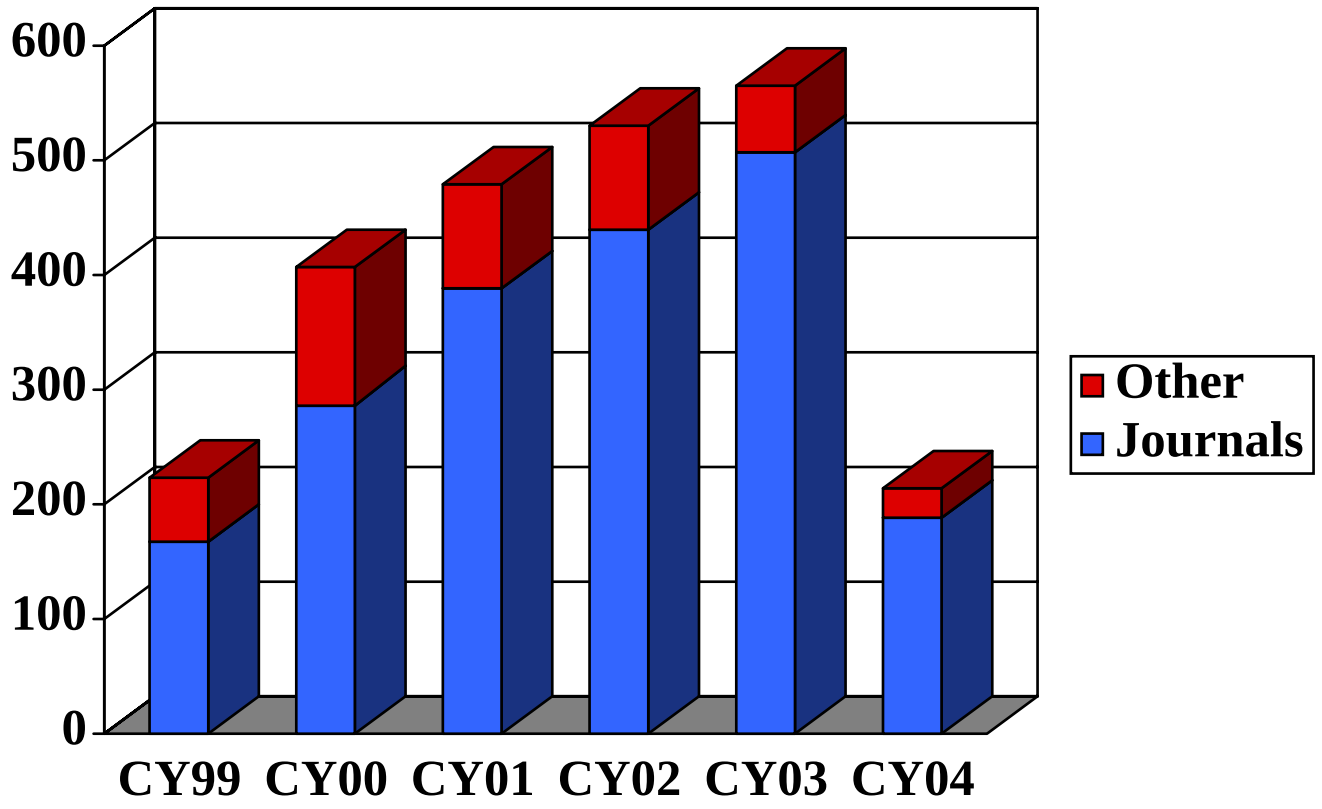
- hard → 2.6 - 45 keV
- soft → 0.5 - 3.0 keV



User Community



APS Users Publications



Summary

- *Basic operational features of the APS introduced*
- *X-ray scattering cross section - magnetism emphasized - outlined*
- *Dedicated beamlines for magnetism studies introduced*
- *Healthy growth of the users community shown*

D. Keavney, J. Freeland, D. Haskel, K. Attenkoffer and J. Lang ⇒ specific examples